

SPACE POWER OPERATION

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MONTHLY PROJECT STATUS REPORT

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JANUARY 31, 1961 Mp

(NASA CR-52538)

HEAT TRANSFER DEVELOPMENT PROGRAM

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Space Power Operation

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

(NASA CONTRACT NUMBER NAS 5-81)

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Dept.
GENERAL ELECTRIC COMPANY

CINCINNATI 15, OHIO

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SUMMARY. The boiler test section design has been completed and fabrication is being investigated. Analyses have been made of the principal thermal stresses. Some design modifications to minimize stress concentrations and to reduce temperature gradients in structural parts have been made. Pressure drop and heat transfer performance have been analyzed to confirm the operating range and specification for the loop components.

The specification for test section instrumentation is being prepared. Secondary temperature standards, based on NBS developments with resistance thermometers and optical pyrometers are being reviewed. Thermocouples stability information is being surveyed to permit selection of couple materials. Pressure drop measurements using diaphragm gages at high temperatures with sodium appear to present a problem.

The size of the condenser test sections has been established for a horizontal and a vertical unit. The use of two condensers in different attitudes is expected to provide information related to gravity force effects.

The facility piping design layout is in preparation, based on existing component design information. Component procurement efforts are continuing. The major critical items not presently on order are the L-605 valves. Design of auxiliary components, operating instrumentation, and control equipment has been initiated.

Capsule testing has begun of L-605 to determine potassium purity level requirements, safe operating temperatures, and carbon transfer problems. Aging studies for L-605 appear to indicate there is no need for low carbon material.

A complete review of the project schedule has been made, based upon the most definitive design information plus discussions with major component vendors. The tentative target date for operation of the 300 KW loop is September 1, 1961. A detailed schedule has been prepared which indicates the status of effort and the items comprising the 300 KW loop. The schedule for the high temperature 100 KW loop is to be defined during February.

TEST SECTION DESIGN. The first boiling test section will be a counter flow, tube and annulus design. Potassium will enter the tube in the saturation condition and flow upward as it is boiled. The tube is .880 inches I.D. and has an active heated length of 50 inches. During the course of the program additional diameters and L/D ratios will be tested. The tube wall thickness is .060 inches which provides adequate material to imbed thermocouples in

a way which will not interfere with the flow. The use of molybdenum for the tube material will minimize temperature drop in the wall at high heat fluxes. The heating fluid will enter the annulus at the top and flow downward at high velocity. The annulus thickness is a compromise between heat transfer coefficient and pressure drop. To minimize the instrumentation complexity, the heating fluid temperature will be measured by thermocouples attached to the outer wall. The temperature difference between the outer tube and the inner tube surface will be directly related to the heat transfer coefficient. The data of R. N. Lyon has been used to optimize this thickness. More recent data from Purdue has been requested to verify this analysis. A complete analysis of these parameters will be included in the Quarterly Report.

The large temperature differences at rated power in the top end of the test section give rise to high thermal stresses particularly in the region of the tube attachment to the discharge header. An insulating sleeve and use of well rounded corners have been incorporated to alleviate this situation.

Thermal cycling of a test Mo-L605 bimetal joint between 1800°F and 300°F has shown good integrity for 10 cycles. A final test of 100 cycles will be performed before the joint design is considered acceptable. The maximum rate of cooldown has been approximately 100°F per minute which exceeds that anticipated for the loop even under emergency conditions.

The final test section instrumentation selection is under study. Two secondary standards are considered highly promising for the 1800°F loop. The Bureau of Standards has under development a resistance thermometer which appears applicable to the test section design for calibration purposes. An automatic optical pyrometer is also under development which appears to have adequate accuracy and to be more flexible in application. The selection of one of these units will be made on the basis of maximum suitability for loop operation since both appear to have the required accuracy. The problems of thermocouple stability is being investigated. A calibrating device will be used to do screening of assembled sheathed thermocouples at the copper point. The measurement of pressure under high temperature vapor conditions may present a problem in NaK filled diaphragm gages. Several alternate designs are to be reviewed.

The horizontal and vertical condenser test sections have been sized for capacity. The vertical unit will have provisions for heat removal by direct air cooling or radiation to a water cooled jacket with a maximum rating of 150 KW. Surfaces of the gap are to be oxidized to improve emissivity characteristics. The active heat transfer tube is 1.320 inches I.D. with a length of 96 inches. The horizontal unit will have air cooling only, and will be rated at 300 KW. This tube has an I.D. of 2.98 inches and is 108 inches long. Details of design are to be completed in February.

A very pertinent analysis has been prepared by S. Levy "Prediction of Two-Phase Flow from Mixing Length Theory." Single phase turbulent mixing length methods are used to predict two-phase flow. Two-phase density and velocity distributions are derived by treating the two-phase system as a continuous medium where the turbulent exchanges of momentum and density are equal. The first results are in good agreement with experimental data for two-phase pressure drop at high velocity and low quality. At lower velocity and higher quality agreement is not as good, but the use of variable fluid property treatment is expected to improve the correlation. The proposed model reduces two-phase flow to an equivalent single phase permitting extension of the present analysis to heat transfer correlation by means of the Reynolds analogy. It is planned to make such an extension for liquid metals by use of Martinelli's work on low Prandtl number fluids.

FACILITY DESIGN. The piping layout drawing for the 300 KW loop has been issued based on preliminary vendor and test section information. The first revision is now underway to allow greater length in the vertical condenser test section. The process flow diagram was revised with the following changes:

- (1) use full flow hot traps in the system with additional hot trap capacity in the dump tanks,
- (2) reduce the number of valves in the system, and
- (3) delete the expansion tanks.

Preliminary layouts of the remaining loop components have been completed. Vendors have been invited to quote on fabrication. The order for valves was not placed during the month due to vendor delays in quoting. The problems are primarily technical and center about the high cost of machining L-605 and questions involving reliability of L-605 bellows. The use of investment castings has been recommended and is under investigation. Such castings have been used for gas turbine application for some time. The problem is being resolved in conjunction with several potential vendors. The order for the electromagnetic pumps was placed with General Electric Atomic Motor Section. The final revision of the piping layout will be issued during February and all detail drawings will be complete or underway.

The 100 KW facility design is still in its preliminary design stage. The two major uncertainties are the protective atmosphere to avoid contamination of the columbium alloy and the design of the high flux test section. The atmosphere problem is under study in relation to vacuum and inert gas use. Dr. C. F. Bonilla has agreed to review possible test section designs to obtain high heat fluxes from electrical heated units without compromise of the measurements. Layouts of the stainless steel tank have been made. It is intended that the vessel be built as soon as possible in order to prove out the protective atmosphere concept while the remainder of the system is in design and fabrication.

MATERIALS SUPPORT. Analytical procedures are being investigated to provide a method for monitoring the oxygen in potassium before filling and during the operation of the heat transfer loops. The alkyl halide method of oxygen analysis has been modified for use with potassium, and several trial specimens have been analyzed, preparatory to determining the sensitivity of the method. Experiments are in progress to prepare standard potassium-oxygen samples by melting HgO with potassium. Octadecane has been identified as an excellent cover medium for minimizing contamination of the potassium samples. To determine the sodium in potassium, a spectrographic working curve has been established for the 0.3 - 3.0% Na range with $\pm 10\%$ accuracy. Means of improving the accuracy and sensitivity are being examined by using the Stallwood Jet.

For the use of L-605 (Haynes Alloy No. 25) as the 300 KW loop construction material, specifications for the fabrication, welding, and inspection are largely completed. Investigations are in progress to document several aspects of the metallurgy of L-605 which are pertinent to the use of this material for the heat transfer loop. An L-605 thermal convection loop has been constructed and is ready for filling as the initial step in a series of corrosion investigations with potassium liquid and vapor. L-605 test capsules and specimens will be placed on test next month to conduct a study of corrosion and the kinetics of carbon depletion of L-605 by hot trapping materials, e.g. zirconium. (At present, it is planned to include a hot trap

in the 300 KW loop which will tend to getter carbon from the L-605 in preference to permitting a possible local increase of carbon in the L-605 by mass transfer.) In addition, some of the properties of extra low carbon L-605 (0.02% nominal) are being examined.

The aging and decrease in ductility which can occur in L-605 during service is being investigated with the low carbon material and the normal L-605 (0.1% C). Table I shows the dependence of the room temperature bend ductility upon annealing in air at various times and temperatures. The largest decrease in ductility, which occurred at 1600°F, does not appear to be strongly influenced by the carbon content. While none of the specimens was totally brittle, the decrease in ductility was very significant, and this will be investigated further by aging welds and during the evaluation of the capsule corrosion test specimens. In addition, experiments involving heat treatment near 1850°F will be investigated to determine whether prior over-aging can be used to minimize the decrease in ductility which occurs in the 1600°F temperature range.

To investigate the effects of a vacuum environment and the low carbon content on the stress-rupture characteristics of L-605, the 0.02% C material was tested at 1900°F. With a 4000 psi load, a life of 192 hours was obtained (8.6% elong.). These are typical values for normal L-605 tested in air.

TABLE I

RESULTS OF BEND TESTS ON AGED L-605

MATERIAL and TREATMENT	AGING TEMP. °F	DEGREES BENT OVER A 1-T RADIUS PRIOR TO CRACK INITIATION			
		Aging Time, Hours			
		50	100	500	1000
Normal L-605 Solution Annealed 2250°F-1 hr, WQ	1400	180	83	41	27
	1600	56	33	15	8
	1800	60	48	38	85
Low Carbon L-605 Solution Annealed 2250°F-1 hr, WQ	1400	180	180	103	82
	1600	174	54	24	12
	1800	62	39	37	46

Material was .063 in. sheet stock, and all aging was carried out in still air.

In order to estimate the material loss by oxidation, tests were conducted for 200 and 500 hours at 1800°F in still air, using both the normal and 0.02%C material. The specimens were cycled by cooling to room temperature every 24 hours. On the basis of linear oxidation, a material loss of 35 mils per side can be expected in 10,000 hours. No appreciable difference in the oxidation rate was noted between the two temperatures, times, and materials. The oxidation investigation is now being extended to examine the effect of combustion products in the atmosphere.

Considering all of the comparative experiments with normal and low carbon L-605, there have been no indications of a very significant difference between the two materials. Therefore, it appears that decarburization of the L-605 by the inclusion of a hot trap in the heat transfer loop will not substantially influence the material behavior. This will be investigated further in conjunction with the examination of specimens obtained from the test capsules which contain potassium and a getter.

In order to use a molybdenum tube in the 300 KW loop test section, the joining of L-605 to 0.5 Ti-Mo is being investigated. Several brazed and diffusion bonded joint configurations have been examined, and the most promising preliminary results have been obtained with a tongue in groove joint design brazed with H-33 (21 Cr-21Ni-8Si-3.5W-0.4C-0.8B-bal. Co). Five of these tube-to-joints have been brazed without producing visual cracks, and they are being tested to examine long-time thermal stability

and resistance to thermal cycling. In addition, specimens of the H-33 brazing alloy are prepared for inclusion in the capsule corrosion tests to be conducted next month.

PROJECT SCHEDULE. A tentative schedule is attached for the 300 KW loop. The details of planning for this loop are taken from established vendor commitments and estimated delivery of those components not presently on order. The critical area appears to be in the piping design since final dimensions to allow prefabrication must be based upon vendor component outlines. The target date of September 1, 1961, for operation appears possible but will require a major effort to define detail designs early and expedite deliveries. The lack of wide spread vendor experience with L-605 can cause unforeseen delays but the know-how of Haynes and General Electric in fabricating this material will be made available whenever it can be useful.

The schedule for the 100 KW high temperature loop is still under study.

It is expected that a tentative schedule will be completed in February.

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